

The background of the entire page is a close-up photograph of a person's face, showing the eyes, nose, and mouth. Overlaid on this photograph are several diagrams of facial muscles. In the upper left, there is a detailed diagram of a muscle with vertical lines and two horizontal wavy lines indicating contraction. To the right of this, there are several red and blue line drawings of muscle fibers and their attachment points on the face. The overall color palette is warm, with yellows, oranges, and reds, accented by the blue and red of the diagrams.

MUSCLEHEADS

Our faces have 44 muscles, most of which contract in a single way. Some muscles, such as those in our foreheads, can move in several ways. Scientists have defined these various movements in “facial action codes,” which they program computers to recognize. From Paul Ekman & Wallace Friesen, The Facial Action Coding System, originally published by Consulting Psychology Press, 1978.

Facing *the* TRUTH

**A New Tool to Analyze
Our Expressions**

By Nancy Ross-Flanigan

A curled lip, a furrowed brow—sometimes even a small change in expression can reveal far more than words. We all like to think we can read people's faces for signs of their true emotions. Now, a computer program can analyze images of faces as accurately as trained professionals.



What's more, it does so faster. Working frame by frame, the most proficient human experts take an hour to code the 1,800 frames contained in one minute of video images, a job that the computer program does in only five minutes. A team led by HHMI investigator Terrence Sejnowski reported the

feat in the March 1999 issue of the journal *Psychophysiology*.

The automated system, which has been improved since the article appeared, could be a boon for behavioral studies. Scientists have already found ways, for example, to distinguish false facial expressions of emotion from genuine ones. In depressed individuals, they've also discovered differences between the facial signals of suicidal and nonsuicidal patients. Such research relies on a coding system developed in the 1970s by Paul Ekman of the University of California, San Francisco, a coauthor of the *Psychophysiology* paper. Ekman's Facial Action Coding System (FACS) breaks down facial expressions into 46 individual motions, or action units.

Sejnowski's team designed the computer program to use the same coding system. Their challenge was to enable the program to recognize the minute facial movements upon which the coding system is based. Other researchers had come up with different computerized approaches for analyzing facial motion, but all had limitations, says Sejnowski, who is director of the Computational Neurobiology Laboratory at The Salk Institute for Biological Studies in La Jolla, California, and a professor of biology at the University of California, San Diego (UCSD). A technique called feature-based analysis, for example, measures variables such as the degree of skin wrinkling at various points on the face. "The trouble," Sejnowski explains, "is that some people don't wrinkle at all and some wrinkle a lot. It depends on age and a lot of other factors, so it's not always reliable."

His team—which included Ekman, Marian Stewart Bartlett of UCSD and Joseph Hager of Network Information Research Corp. in Salt Lake City—took the best parts of three existing facial-motion-analysis systems and combined them.

"We discovered that although each of the methods was imperfect, when we combined them the hybrid method performed about as well as the human expert, which is at an accuracy of around 91 percent," Sejnowski says. The computer program did much better than human nonexperts,

Sejnowski is most interested in using the system to explore information processing in the human brain. He likes to think of the brain's changing activity patterns as "brain expressions," similar in many ways to facial expressions.

who performed with only 73.7 percent accuracy after receiving less than an hour of practice in recognizing and coding action units. The coding process involves identifying and marking sequences of frames in which an individual facial expression begins, peaks and ends. A minute of video can contain several hundred action units to recognize and code.

In the work reported in *Psychophysiology*, the researchers taught the computer program to recognize 6 of the 46 action units. Since then, the program has mastered six more and, by incorporating new image-analysis methods developed in Sejnowski's lab, the system's performance has risen to 95 percent accuracy. The additional work was published in the October 1999 issue of *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

Now the team is engaged in a friendly "cooperative competition" with researchers from Carnegie Mellon University and the University of Pittsburgh who have developed a similar system. The two systems will be tested on the same images to allow direct comparisons of performance on individual images as well as overall accuracy. The teams will then collaborate on a new system that incorporates the best features of each.

A computer that accurately reads facial expressions could result in a better lie detector, which is why the CIA is funding the joint project. But Sejnowski sees other possible commercial applications as well.

"This software could very well end up being part of everybody's computer," he says. "One of the goals of computer science is to have computers interact with us in the same way we interact with other human beings. We're beginning to see programs that can recognize speech." But humans use more than speech recognition when they communicate with each other, he explains. In face-to-face conversation, "you watch how a person reacts to know whether they've understood what you've said and how they feel about it." Your desktop computer can't do that, so it doesn't know when it has correctly interpreted your words or when it has bungled the meaning. With this software and a video camera mounted on your monitor, Sejnowski thinks your computer might someday read you as well as your best friend does.

Sejnowski and his team are engaged in a friendly "cooperative competition" with other researchers, with whom they will collaborate on improved systems.



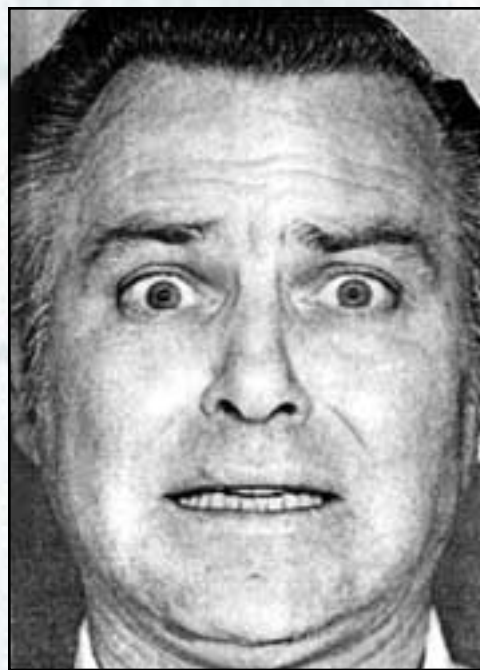
Analyzing Our Expressions

BRIGHT LIGHTS, MOVING HEADS



A computer system has to be taught to “see” someone’s furrowing brow or crinkly smile. Sejnowski and his team have drawn from diverse fields of science, such as artificial intelligence and neural networks, to handle this task. Among the many hurdles they face is head movements and varying light conditions. To overcome this, their system breaks down the images of faces into tiny units, measures the light in each dot, and then compares the mosaic to known facial patterns. It’s a process that resembles—but is far more primitive than—the way our brains make sense of light passing through the eye. In these photos, the smile on the left is false while the smile on the right is real.

BE VERY AFRAID



If the outer part of your eyebrow goes up, you’re probably afraid—although you may just be feeling surprise. To determine whether someone is truly afraid, like the man in this photo, Sejnowski’s team looks for several other facial actions that indicate fear. All of the following movements in the upper part of the face may indicate fear, although some are also associated with other emotions:

- *Raising the upper eyelid to show the whites of the eyes*
- *Raising the inner brow:* Also may show sadness
- *Lowering the brow:* Also may show anger or mental effort
- *Tightening the eyelid:* Also may show anger or disgust

FAKE EXPRESSIONS



Several facial cues suggest that someone is faking an expression, among them:

- The muscle contractions on the left side of the face differ from those on the right side.
- The expressions start and stop in a jerky manner.
- The person holds the expression for too long.

Eye movements also provide information. Someone looking downward may be sad, while someone looking down or away is more likely feeling shame, guilt or disgust. The sad look on this man’s face is false.

A BETTER LIE DETECTOR

No one has yet created an infallible tool to spot a liar. It's only possible to measure a person's emotions and then determine whether these are consistent with the person being truthful. That's the idea behind the polygraph, which measures increases in sweating, heart rate and breathing rate that are associated with heightened emotion. New technology that analyzes faces may improve on this classic "lie detector" by revealing not only the presence of emotion but also the *type* of emotion. For example, a man who is asked "Did you kill your wife?" during a polygraph test might "fail" because he felt either anger or disgust—emotions that cause similar physical reactions but have different implications for innocence or guilt. A facial analysis, on the other hand, might distinguish between anger and disgust, providing police with a valuable insight.

Polygraph tests are not normally admissible in courts of law in the United States, but they are often used when both sides agree in advance, such as for workplace



security clearances. Unfortunately, innocent people sometimes fail the tests, and automatic facial measurement systems are not yet ready to take their place.

Comprehensive systems are still at least 5 to 10 years away, and they will need to be tested extensively before they can even be considered for use in the legal system, the workplace or elsewhere.

A GLIMPSE OF THE TRUTH



True emotions often flash across a person's face in less than a quarter of a second. A person feeling fear or disgust, for example, can cover up with a smile before others realize what happened. A big advantage of computers is that they can analyze videotapes to spot such "microexpressions" more quickly and accurately. Even good actors find it difficult to prevent their faces from revealing this moment of truth, especially if they are unprepared for the question. In this photo, the man's smile is false.

PHOTOS: COURTESY OF PAUL EKMAN

And speaking of best friends, the software could conceivably give robotic pets a leg up on the furry kind. In a project at UCSD, the researchers are integrating their system into the popular robotic dog AIBO, developed by Sony Corp., with the goal of training the robo-pet to recognize individual people and respond to their emotions. For example, says Sejnowski, "AIBO might comfort you if you are upset or play with you if you are restless." The eventual product could be more than just a high-tech toy. With recent research showing health benefits from interacting with pets, an empathic AIBO might be good medicine for people too ill or frail to care for living animals.

Exciting as the commercial prospects may be, Sejnowski says he's most interested in using the system to explore information processing in the human brain. "In the recent work, we find that the best performance comes from a method based on the way that single neurons filter visual images in the very first stage of processing in the visual cortex," he says. "The next step is to see whether or not some of the subsequent stages of processing in the visual system line up with the methods that we've developed."

The new methods are also proving useful in analyzing brain images obtained through functional magnetic resonance imaging. Sejnowski likes to think of the brain's changing activity patterns as "brain expressions," similar in many ways to facial expressions. The goal of his new work is to understand, by analyzing sequences of brain images, how different patterns of neural activity relate to particular tasks the brain is tackling or thoughts that are flickering through it.

"The face expresses what's going on in the brain, but it's only a pale reflection," Sejnowski says. "Now we have the capability, with brain imaging, to actually look inside and see what's going on in the person's mind while they're experiencing an emotion and making the facial expression."